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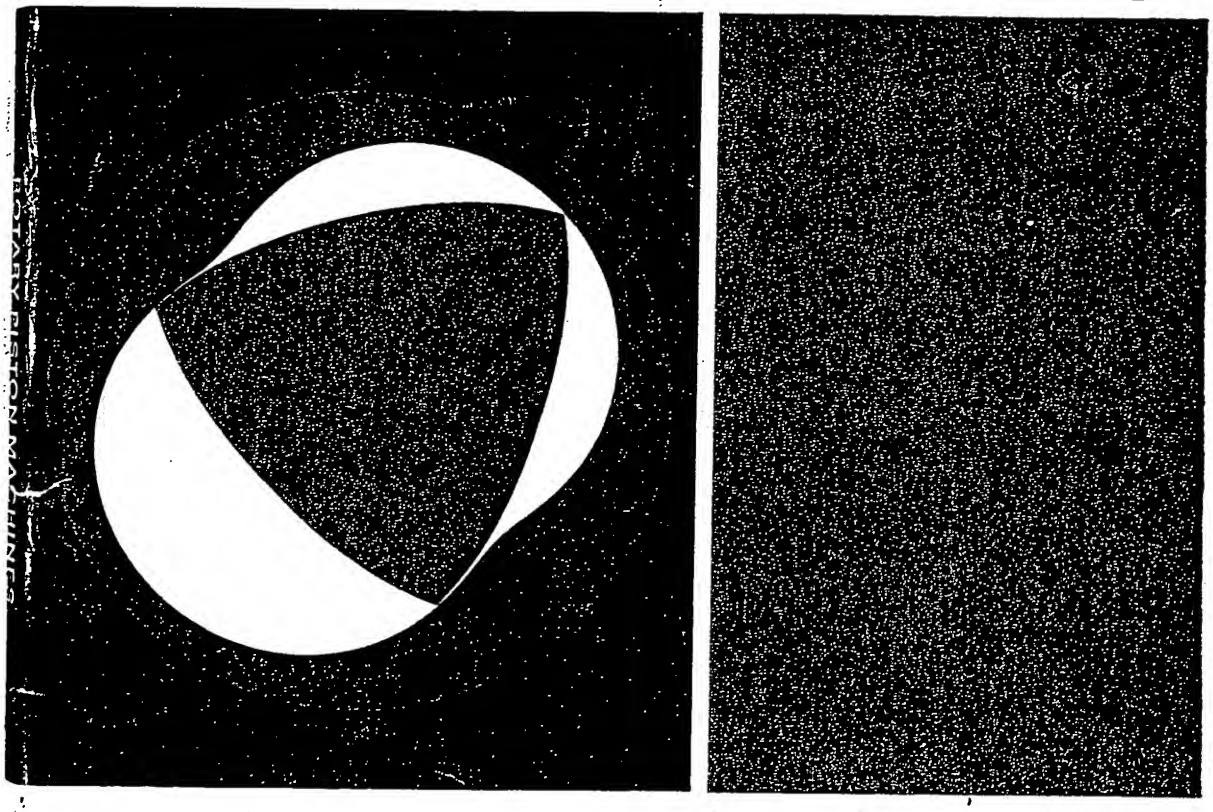
Classification of design principles for engines, pumps and compressors

ROTARY PISTON MACHINES



Felix Wankel

gement (A), cam-engage-
nal (Co) and external-axis

gaging components.

parallel circular arcs. The
equal r.p.m.[1] and equal

of engaging gears.

r.p.m.[1] has fewer teeth[2].
greater number of teeth[2].
p.m. have equal numbers

ar r.p.m.[1] has few[2] teeth.
wer r.p.m.[1] possesses a

ual r.p.m.[1] possess equal

ct point in same direction

possesses fewer[2] teeth.
possesses more[2] teeth.

ngaging point in opposite

n.
of components performing an

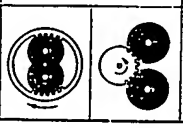
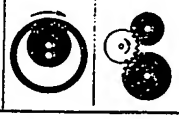
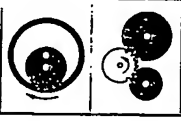
Significance of the colour code

- Piston-runner or rotor (output component)
- Sealing-rotor (sealing component)
- Alternating or simultaneous piston or rotor and sealing component
- Stationary chamber wall
- Crank
- Sealing element

Illustrations of engagement methods

Internal-axis SIM

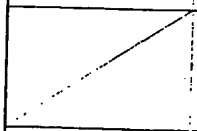
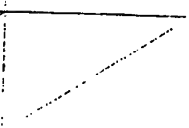
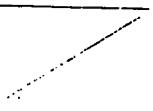
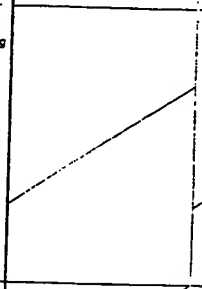
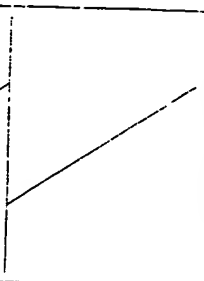
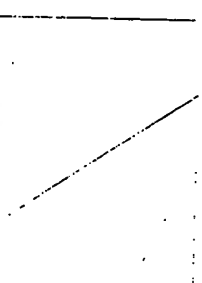
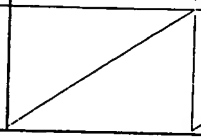
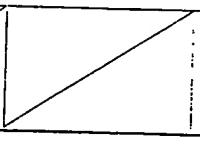
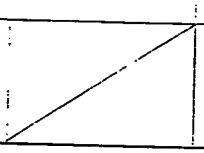
Similar arrangement to the axes of an external-tooth gear meshing with internal tooth ring gear

Principle of Engagement	I. Reciprocating engagement (R)	II. Arctuate engagement (A)	III. Cam engagement (Ce) or (Ci)	IV. Slip engagement (S)	V. Counter engagement (Coi) or (Coe)
Example of models	Inpossible as SIM machines				
Diagrammatic sketch, arrows indicate direction of rotation					
Distinguishing mark		At point of contact the rotating parts move in same direction. Engaging parts pursue parallel circular paths. They revolve at equal r.p.m.	At point of contact motion is in same direction. Engaging component with smaller diameter and higher speed has fewer teeth. Larger diameter part running at lower speed has more teeth.	At contact point rotation in same direction. Larger diameter part with higher speed has fewer teeth. Smaller diameter part with lower speed has more teeth.	Direction of rotation at contact point in opposite direction. Speed ratio may be anything provided it is a whole number.
Gear connections between axes					

2

3 External-axis SIM

Similar to the axes of a pair of meshing spur gears

Principle of Engagement	I. Reciprocating engagement (R)	II. Arctuate engagement (A)	III. Cam engagement (Ci) or (Ce)	IV. Slip engagement (S)	V. Counter engagement (Coi) or (Coe)
Exemple of models	Impossible as SIM machines	Impossible with external-axis SIM machines		Cam engagement cannot form chambers on external-axis machines.	
Diagrammatic sketch, arrows indicate direction of rotation					
Distinguishing mark			At contact point rotetion in same direction. Component with equal or unequal diameter and higher speed has fewer teeth. Component with equal or unequal diameter and lower speed has more teeth. Component with equal or unequal diameter end equal speed has equal number of teeth.		Direction of rotation at contact point in opposite direction. Speed ratio may be anything provided it is a whole number.
Gear connections between axes					

4 Internal-axis PLM with inner piston-rotor similar to the arrangement of axes of pinion and internal-tooth ring gear, the piston-rotor revolving about its own centre of gravity

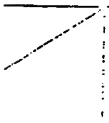
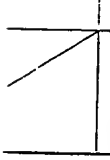
Principle of Engagement	I. Reciprocating engegement (R)	II. Arctuate engagement (A)	III. Cam engagement (Ci) or (Ce)	IV. Slip engegement (S)	V. Counter engagement (Coi) or (Coe)
Example of models					 Sealing component if present = crank
Diegrammatic sketch, arrows indicate direction of rotation					
Distinguishing mark	Linear motion between the engaging components. Piston-rotor rotates in opposite direction to crank et half crank speed relative to housing. Sealing component also rotetes in same direction at half crank speed relative to casing.	Circular parallel motion of the engaging components. Piston-rotor revolves in opposite direction to crank but at the same speed as the crank reletive to the casing.	Rolling motion at engagement point. Piston-rotor revolves in opposite direction to crank but et higher speed than the crank reletive to casing. Engeging component with smaller diemeter and higher speed hes smaller number of teeth. Engaging component with lerger diameter has more teeth.	Rolling motion at engaging point. Piston-rotor revolves in opposite direction to crank but at lower speed reletive to casing. Engaging component with lerger diameter has fewer teeth. Engaging component with smeller diameter and lower speed has more teeth.	Counter movement at point of contact. Piston-rotor revolves at equal speed round crank pin at any speed ratio to crenk relative to casing provided it is a whole number.
Gear connections between axes					

Internal-axis PLM with outer piston-rotor rotating about its own

Principle of Engagement	I. Reciprocating engagement (R)
Example of models	
Diagrammatic sketch, arrows indicate direction of rotation	
Distinguishing mark	Linear motion between the engaging componen Piston-rotor rotates in opposite direction to crank at half crank spee relative to housing. Sealing component alsc rotates in same directio at half crank speed relative to casing.
Gear connections between axes	

External-axis PLM have axes which itself follows a circular path

Principle of Engagement	I. Reciprocating engagement (R)
Example of models	
Diagrammatic sketch, arrows indicate direction of rotation	
Distinguishing mark	Linear motion of engag components. Piston-rotor revolves ir opposite direction to crank and et the seme speed relative to the casing. Crankshafts rotete in opposite directions.
Gear connections between axes	

gagement (S)	V. Counter engagement (Coi) or (Coe)
gement cannot ers on is machines.	
	
Direction of rotation at contact point in opposite direction. Speed ratio may be anything provided it is a whole number.	
	

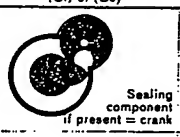
id internal-tooth ring gear, the

gement (S)	V. Counter engagement (Coi) or (Coe)
	 Sealing component if present = crank
	
at volves in tion to wer speed ing. ponent with r has ponent ameter d has	Counter movement at point of contact. Piston-rotor revolves at equal speed round crank pin at any speed ratio to crank relative to casing provided it is a whole number.
	

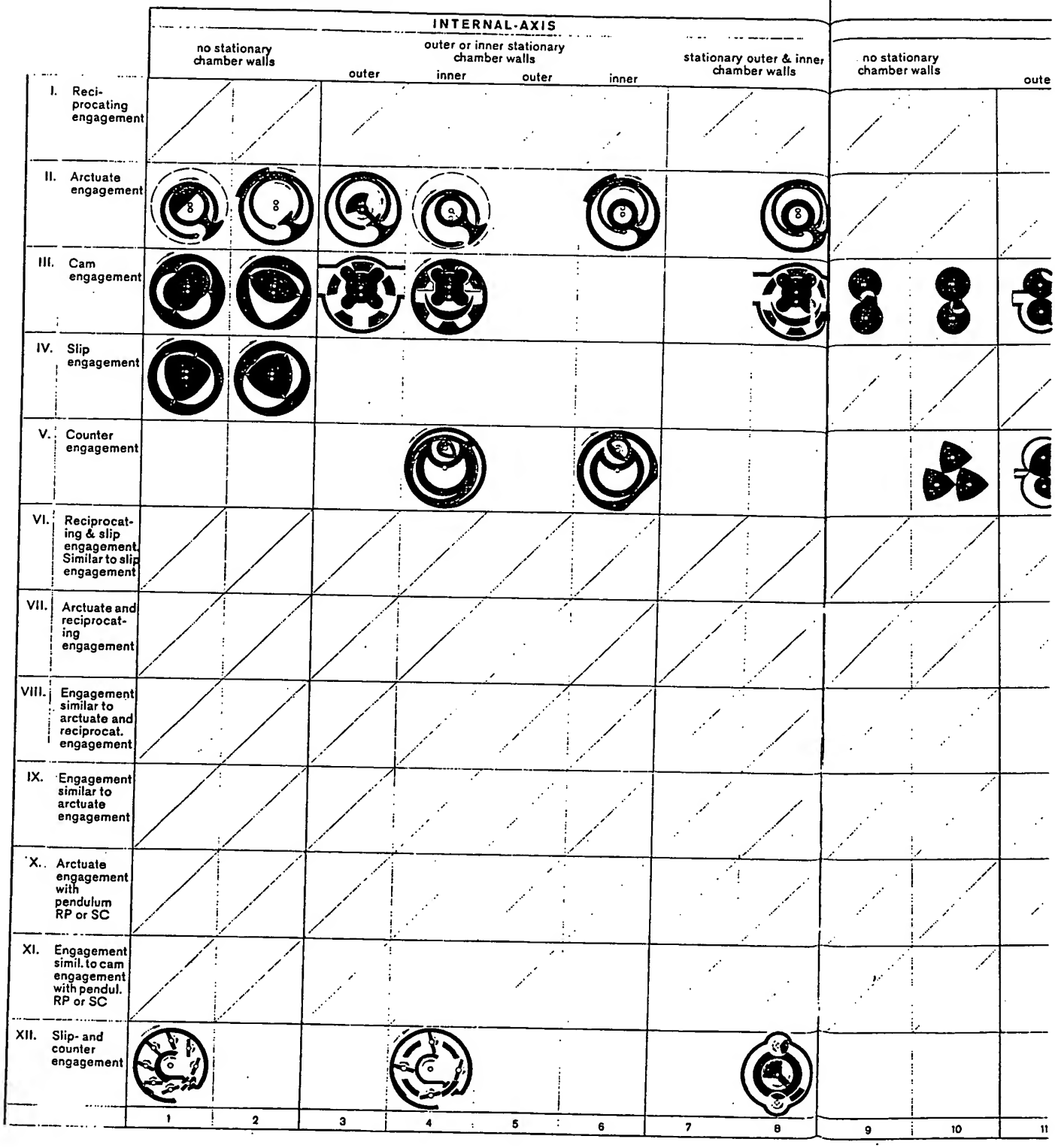
Internal-axis PLM with outer piston-rotor similar to the arrangement of axes of pinion and internal tooth ring gear, piston-rotor rotating about its own centre of gravity **5**

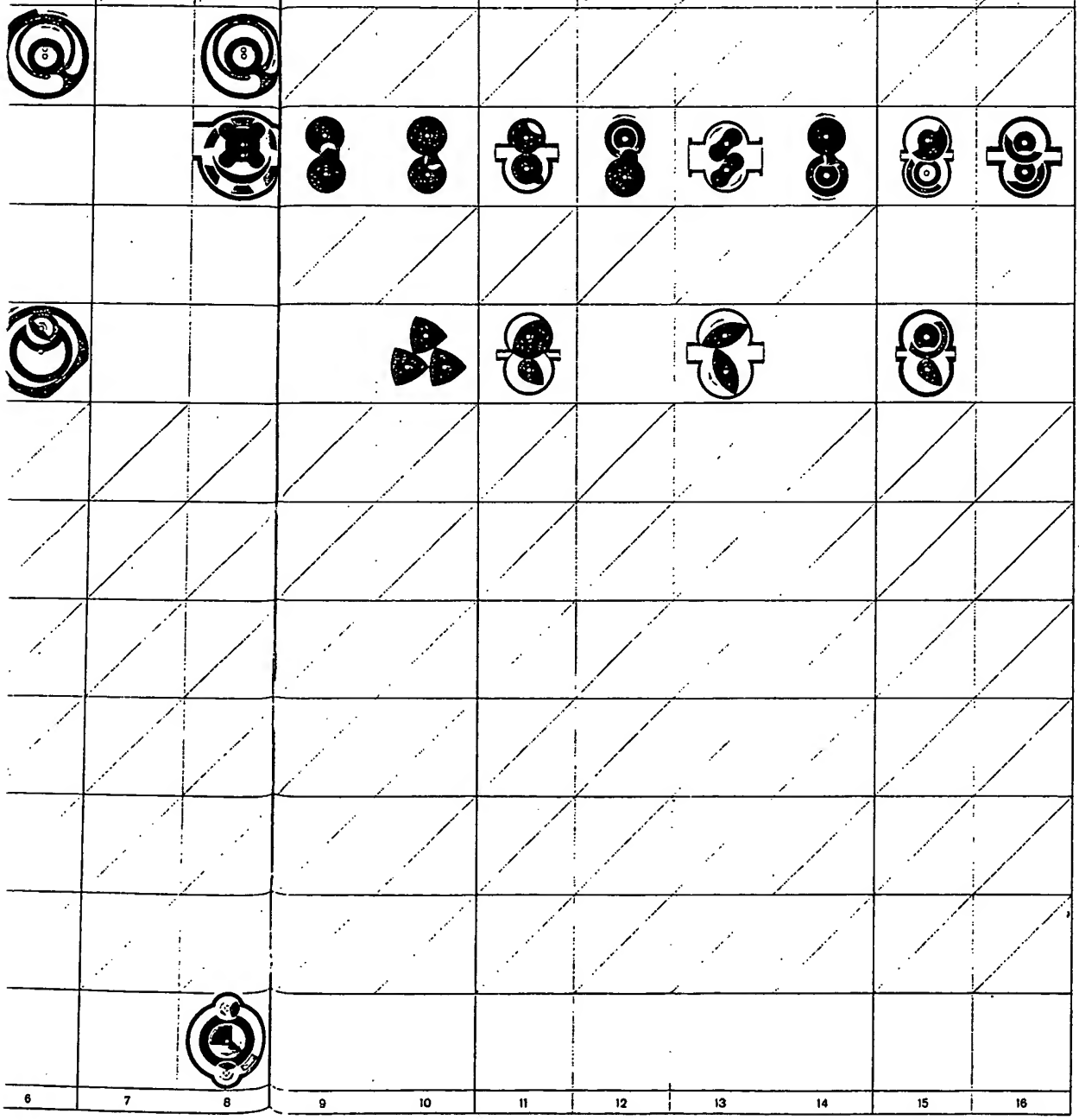
Principle of Engagement	I. Reciprocating engagement (R)	II. Arctuate engagement (A)	III. Cam engagement (Ci) or (Ce)	IV. Slip engagement (S)	V. Counter engagement (Coi) or (Coe)
Example of models					
Diagrammatic sketch, arrows indicate direction of rotation					
Distinguishing mark	Linear motion between the engaging components. Piston-rotor rotates in opposite direction to crank at half crank speed relative to housing. Sealing component also rotates in same direction at half crank speed relative to casing.	Circular parallel motion of the engaging components. Piston-rotor revolves in opposite direction to crank but at the same speed as the crank relative to the casing.	Rolling motion at engagement point. Piston-rotor revolves in opposite direction to crank at lower speed than the crank relative to casing. Engaging component with smaller diameter has fewer teeth. Larger diameter part with lower speed has more teeth.	Rolling motion at engagement point. Piston-rotor revolves in opposite direction to crank at higher speed relative to casing. Engaging component with larger diameter and higher speed has fewer teeth. Larger diameter part has more teeth.	Counter movement at point of contact. Piston-rotor revolves at equal speed round crank pin at any speed ratio to crank relative to casing provided it is a whole number.
Gear connections between axes					

External-axis PLM have axes similarly arranged to meshing spur gears and the rotating piston-rotor revolves round its c.g. which itself follows a circular path **6**

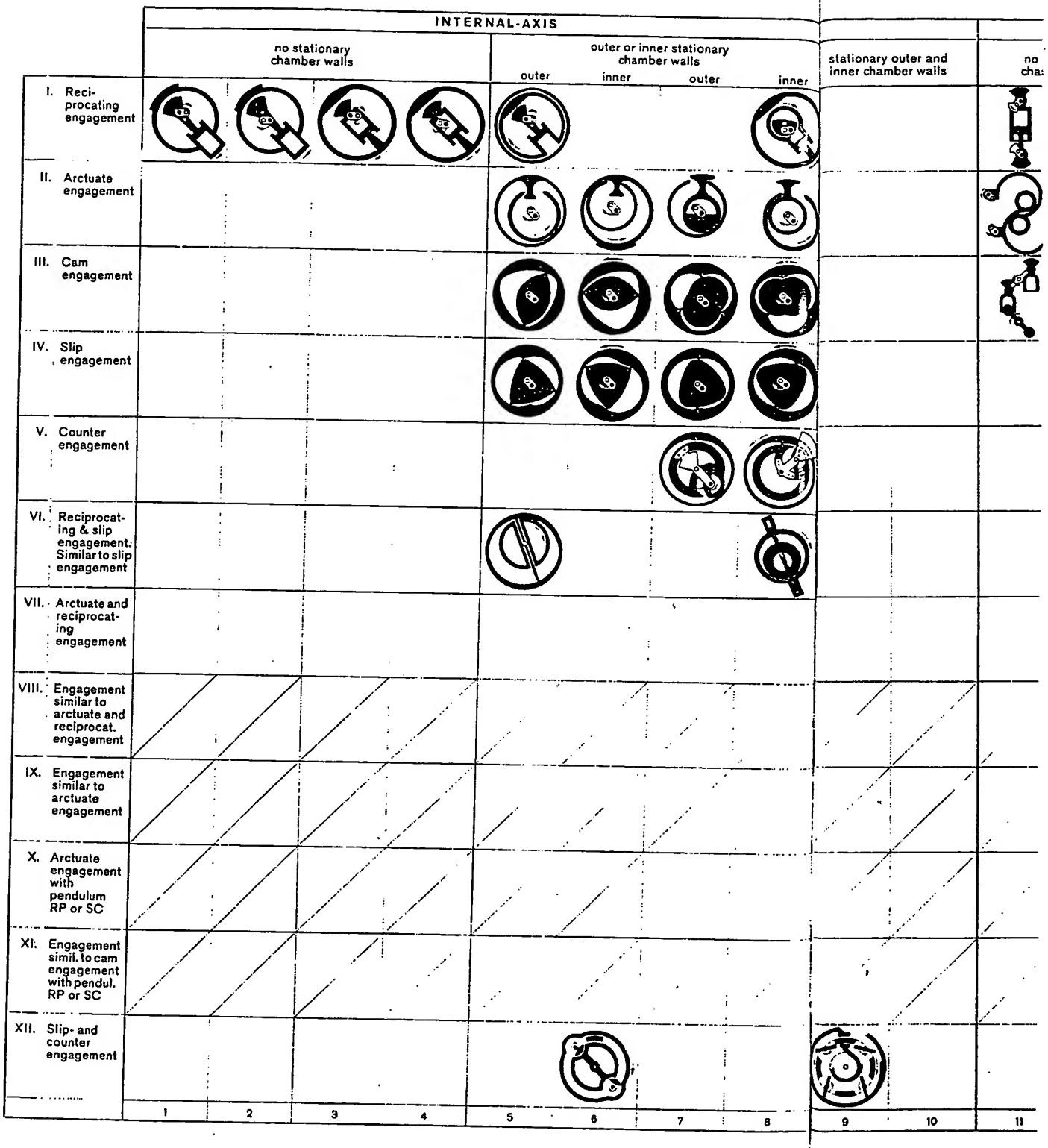
Principle of Engagement	I. Reciprocating engagement (R)	II. Arctuate engagement (A)	III. Cam engagement (Ci) or (Ce)	IV. Slip engagement (S)	V. Counter engagement (Coi) or (Coe)
Example of models			 Sealing component if present = crank	Cam engagement cannot form chambers on external-axis machines.	 Sealing component if present = crank
Diagrammatic sketch, arrows indicate direction of rotation					
Distinguishing mark	Linear motion of engaging components. Piston-rotor revolves in opposite direction to crank and at the same speed relative to the casing. Crankshafts rotate in opposite directions.	Circular parallel motion of the engaging components. Piston-rotor revolves in opposite direction to crank and at the same speed relative to casing. Crankshafts rotate in the same direction.	Rolling motion at engaging point. Piston-rotor revolves in the same direction relative to housing. Engaging component with equal or unequal diameters and higher speeds have fewer teeth. Engaging component with equal or unequal diameters and lower speeds have more teeth. Engaging component with equal or unequal diameters have equal number of teeth.		Counter rolling movement at contact point. Piston-rotor revolves in opposite direction to crank pin at any speed ratio relative to crank, provided it is a whole number.
Gear connections between axes					

7 Classification of single-rotation machines (SIM)

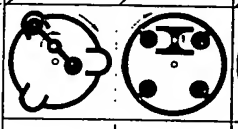
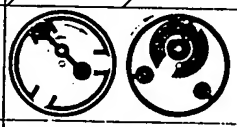
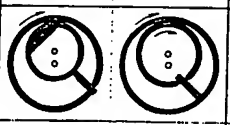



EXTERNAL-AXIS
inner
stationary outer & inner chamber walls
no stationary chamber walls
outer or inner stationary chamber walls
outer
inner
outer
inner
stationary outer & inner chamber walls
6
7
8
9
10
11
12
13
14
15
16

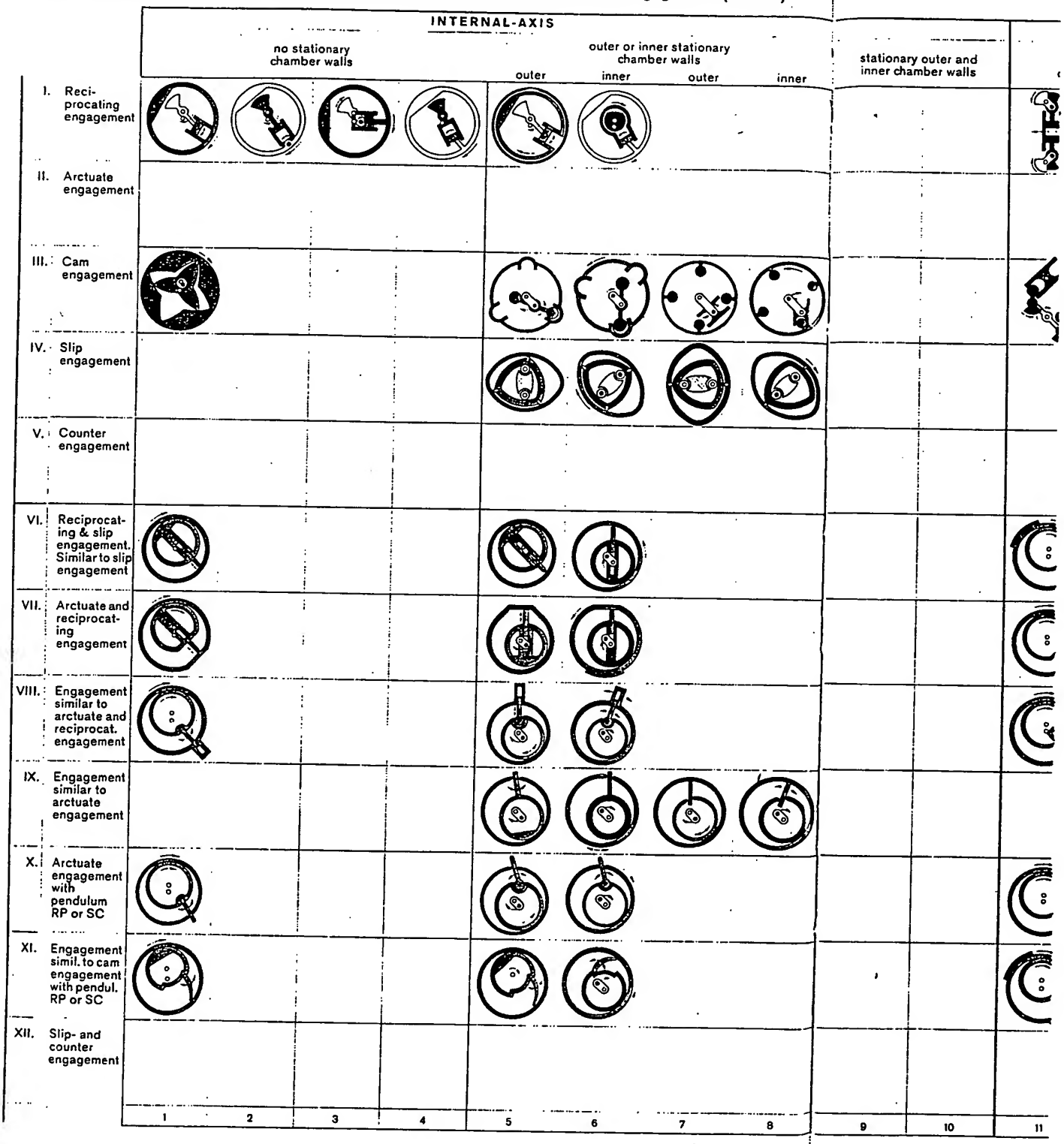
8 Classification of planetary-rotation machines (PLM)

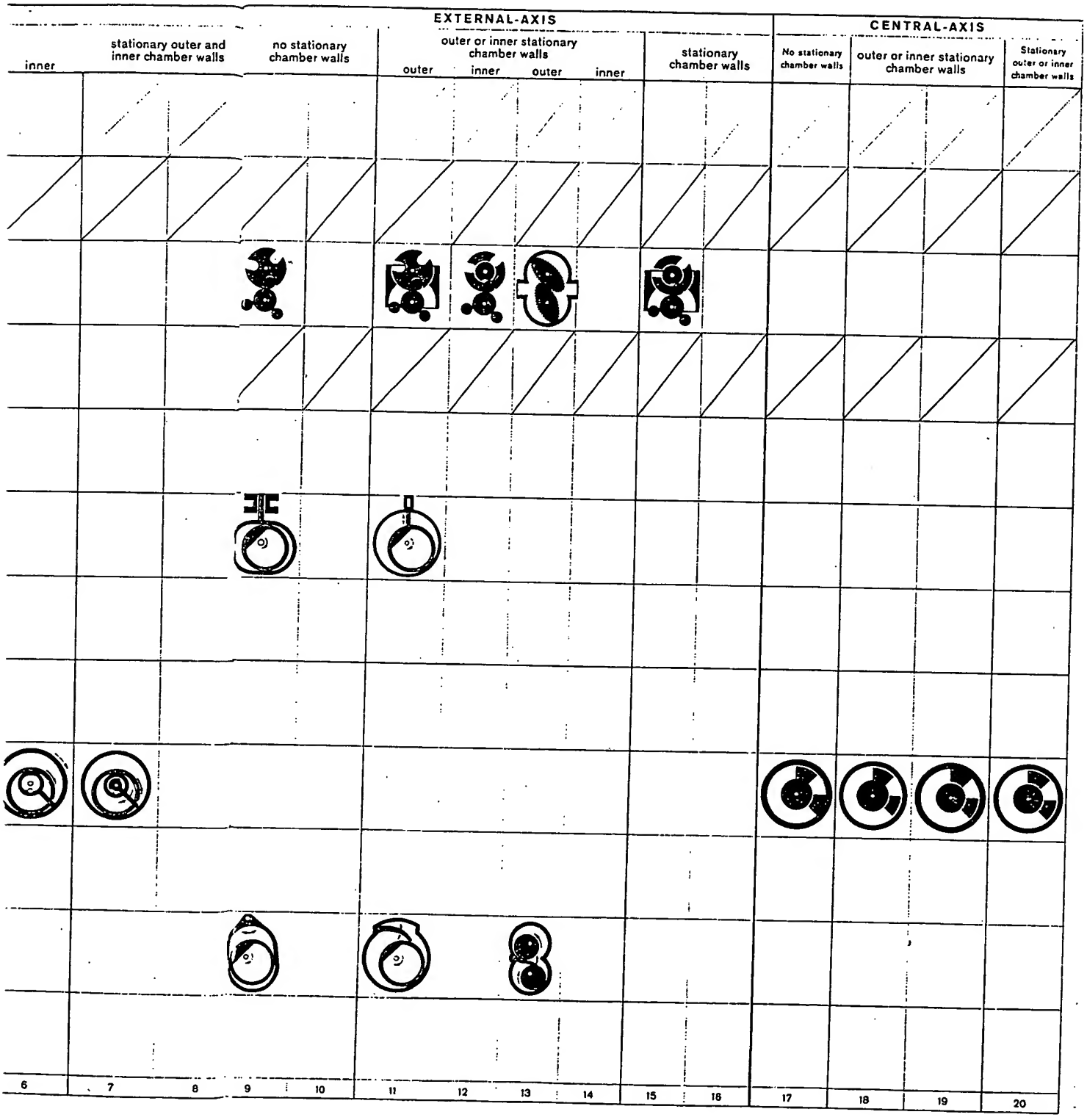


9 Classification of single-rotation rotating-piston machines (SROM)

	INTERNAL-AXIS								EXTE			
	no stationary chamber walls		outer or inner stationary chamber walls				stationary outer and inner chamber walls		no stationary chamber walls		oute	
			outer	inner	outer	inner					outer	
I. Reciprocating engagement												
II. Arctuate engagement												
III. Cam engagement												
IV. Slip engagement												
V. Counter engagement												
VI. Reciprocating & slip engagement. Similar to slip engagement												
VII. Arctuate and reciprocating engagement												
VIII. Engagement similar to arctuate and reciprocat. engagement												
IX. Engagement similar to arctuate engagement												
X. Arctuate engagement with pendulum RP or SC												
XI. Engagement simil. to cam engagement with pendul. RP or SC												
XII. Slip- and counter engagement												
	1	2	3	4	5	6	7	8	9	10	11	

10 Classification of rotating-piston machines with engagement similar to arctuate engagement (PROM)




EXTERNAL-AXIS
CENTRAL-AXIS
inner
stationary outer and inner chamber walls
no stationary chamber walls
outer or inner stationary chamber walls
outer
inner
outer
inner
stationary chamber walls
No stationary chamber walls
outer or inner stationary chamber walls
Stationary outer or inner chamber walls
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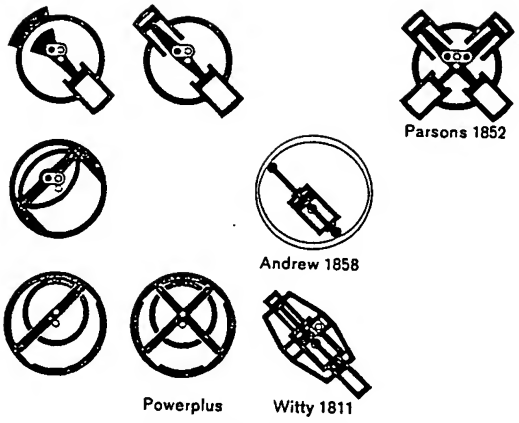
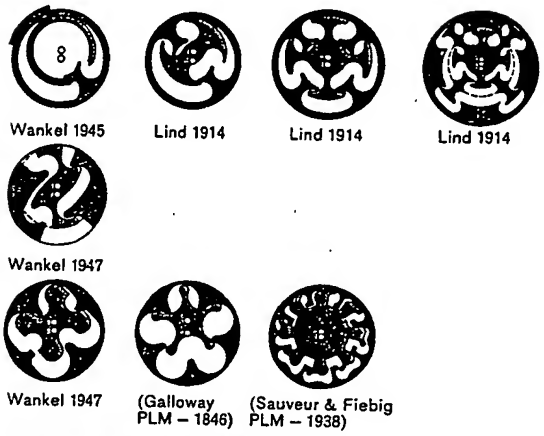
11 **Model Sheet**



Types of internal-axis machines PLM (R) Chart 8 I/1

Types of interr

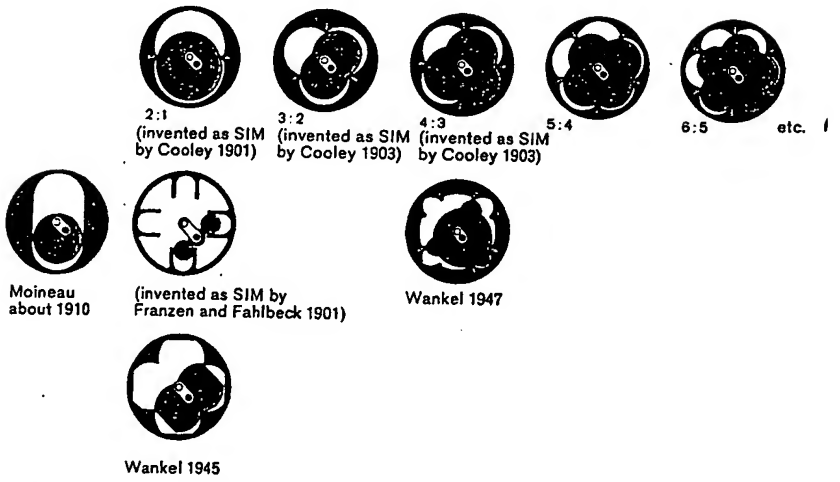
12 **Model Sheet**



Types of internal-axis machines SIM (A) Chart 7 II/2

Types of intern

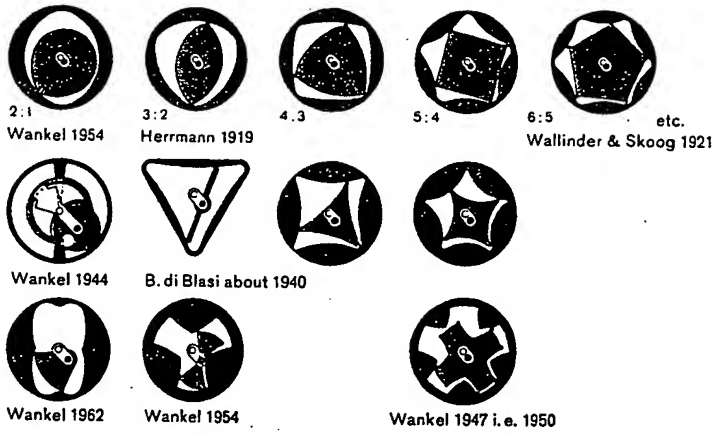
13 **Model Sheet**



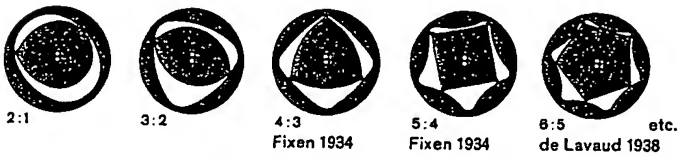
Types of internal-axis PLM (Ce) Chart 8 (PLM) III/7

Types of intern

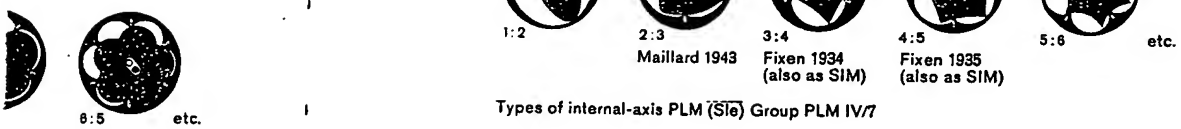
Types of intern



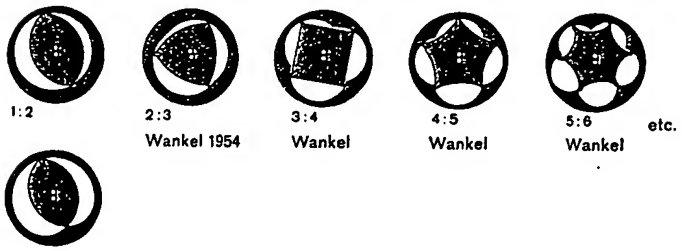
Types of internal-axis PLM $\overline{(Ci)}$ Group PLM III/5



Types of internal-axis SIM $\overline{(Ci)}$ Group SIM III/2



Types of internal-axis PLM $\overline{(Sle)}$ Group PLM IV/7



Types of internal-axis SIM $\overline{(Sli)}$ Group SIM IV/2

18 **Model Sheet**

1:2 E. Galloway 1834 | 2:3 Wankel 1954 | 3:4 Wankel | 4:5 Wankel | 5:6 Wankel etc.

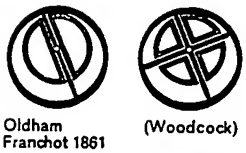
Types of internal-axis PLM ($\dot{S}\bar{I}i$) Group PLM IV/5

Internal-axis PLM
IV Slip-engageme

Internal-axis PLM
III Cam-engagem

ROPIMA machine

19 **Model Sheet**



Oldham Franchot 1861 | (Woodcock)

J. T. Beale 1877 | Zoller about 1925

Powerplus about 1925

Wankel 1945

Types of internal-axis PLM $\overline{(S+R)}$ Group PLM VI/5

Ramelli 1588

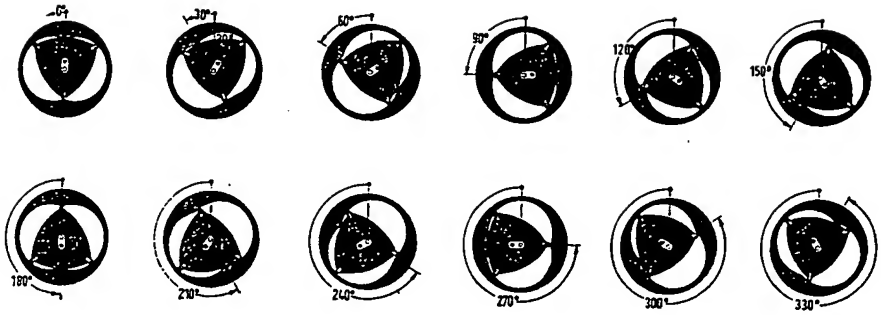
Emery 1869

Types of internal

Trotter 1805 C

Types of internal-

20 **Phasing Diagram**



Diagrammatic arrangement of relative rotor positions of 2:3 machine, outer rotor has additional PLM rotation

T

Types of external-

etc.

Internal-axis PLM (Sli)
IV Slip-engagement 2 : 3

Internal-axis PLM (Sle)
III Cam-engagement 3 : 2

Dillenberg 1961
Internal-axis PROM
IX Arctuate-engagement

Internal-axis PLM (Sle)
III Cam-engagement 2 : 1

Internal-axis PLM (Sle)
III Cam-engagement 2 : 1

ROPIMA machines with additional motion which is not required

Ramelli 1588

Wittig about 1900

Emery 1869

Davies 1867

Jones & Shirreff 1856

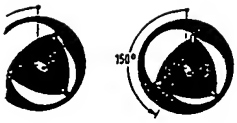
Types of internal-axis PROM machines Group PROM VI/5

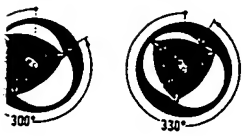
Trotter 1805

Cochrane 1830

Fletcher 1843

Types of internal-axis SROM machines Group SROM IX/3





or has additional PLM rotation

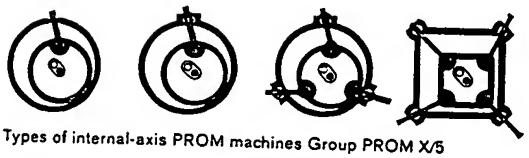
Tänzler 1937

Tänzler 1937

Tänzler

Types of external-axis PROM machines Group PROM X/11

25 Model Sheet



Types of internal-axis PROM machines Group PROM X/5

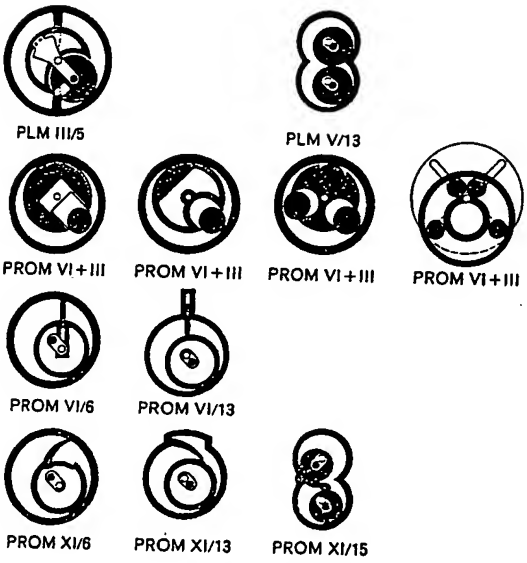
26 Model Sheet

Ramelli 1588 Cochrane Turboflex

Geiger 1960 Sugopump

Types of internal-axis PROM machines Group PROM XI/5

27 Sheet of Comparisons



PLM and PROM machines with rolling-piston rotor

Special Ter
Rotary Pist

HKM = Hubkolb
RKM = Rotation
DKM = D = Dre
KKM = K = Kre
UKM = Umlaufk
DU = Drehkolb
Umlaufk
KU = Kreiskoll
Umlaufk
(K) = Kammein
(S) = Schlupfei
(KR) = Kreiseing
(G) = Gegenei
(H) = Hubeingr
* Parallelachsige
* Parallel-außena
* Parallel-innenac
* Mittelachsige M
* Winkelachsige
* Winkel-außenac
* Winkel-innenac
* Geschränktachs
* Geschränkt-auß
* Geschränkt-inne
Bauarten
Bauformen
Schwerpunktverh.
Kolbenlaufer KL
Schwingbaum
Wagnerscher Han

Absperrteil = AL

Einteilungs- oder
Umlaufkolben-Ste
Kurvenerzeugung
Verzahnungskörp
Paarkolben
Paarflügelkolben
Paarschieber
Eingriffskörper
Arenakurven
Schädlicher Raum
Kardenkreisgeset
Kardankreisgetrie
Querzylindrisch
Ovalzahnräder

Special Terms and Expressions Used in Conjunction with Rotary Piston Machines

HKM = Hubkolbenmaschine	REM = reciprocating-piston machine
RKM = Rotationskolbenmaschine	ROPIMA = Rotary piston machine
DKM = D = Drehkolbenmaschine	SIM = Single rotation machine
KKM = K = Kreiskolbenmaschine	PLM = planetary-rotation machine
UKM = Umlaufkolbenmaschine	ROM = Rotating-piston machine
DU = Drehkolbenartige Umlaufkolben-Maschine	SROM = Rotating-piston machine similar to single-rotation machine
KU = Kreiskolbenartige Umlaufkolben-Maschine	PROM = Rotating-piston machine similar to planetary-rotation machine
$\overline{(K)}$ = Kammeingriff	$\overline{(C)}$ = Cam engagement (or meshing)
$\overline{(S)}$ = Schlupfeingriff	$\overline{(Sl)}$ = slip engagement (or meshing)
$\overline{(KR)}$ = Kreiseingriff	$\overline{(A)}$ = arctuate engagement (in circular arc)
$\overline{(G)}$ = Gegeneingriff	$\overline{(Co)}$ = counter engagement
$\overline{(H)}$ = Hubeingriff	$\overline{(R)}$ = reciprocating engagement
* Parallelachsige RKM	ROPIMA machines with parallel axes
* Parallel-außenachsige RKM	ROPIMA machines with external axes
* Parallel-innenachsige RKM	ROPIMA machines with internal axes
* Mittelachsige Maschinen	Central axis machines
* Winkelachsige Maschinen	Machines with axes inclined towards each other
* Winkel-außenachsige Maschinen	Machines with external axes inclined
* Winkel-innenachsige Maschinen	Machines with internal axes inclined
* Geschränktachsige RKM	ROPIMA intersecting or crossed axis machine
* Geschränkt-außenachsige RKM	ROPIMA intersecting external axis machine
* Geschränkt-innenachsige RKM	ROPIMA intersecting internal axis machine
Bauarten	types
Bauformen	models, versions
Schwerpunktverhalten	behaviour of the centre of gravity
Kolbenlaufer KL	RP = runner, rotor, rotating piston
Schwingbaum	rocking beam or swinging beam
Wagnerscher Hammer	electric bell actuating device said to have been invented by: John Maraud (E) J. P. Wagner (G) Neff (F) Page (USA)
Absperrteil = AL	SC = Sealing or containing components, not sealing element
Einteilungs- oder Systemblatt	classification chart
Umlaufkolben-Sternflugmotor	radial aircraft engine, Gnôme le Rhône
Kurvenerzeugungspunkte	curve generating points
Verzahnungskörper	(tooth) generating part or body
Paarkolben	double, double acting or pair of pistons
Paarflügelkolben	single vane right through rotor
Paarschieber	sliding vane valve
Eingriffskörper	catch, pawl, engating or meshing
Arenakurven	oval track shaped like circus arena
Schädlicher Raum	Volume contained at TDC
Kardenkreisgesetz	Principle of HYPOCYCLOID ($R = 2r$)
Kardankreisgetriebe	Epicyclic or planetary gearbox
Querzylindrisch	Cylinder transverse or parallel to axis of rotation
Ovalzahnräder	Oval gears (used in counting machines)